STATIC SHA 'E CONTROL OF INFLATABLE STRUCTURES

M Salama*, C.P K 10, J .Ga 1a B Wada
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA. 91109

M. Thomas
I esident, L'Garde Incorpora ed
Tustin, CA. 92680

ABSTRACT

Inflatable structural concepts have been proposed for numerous applications [1-5] such as antennas for microwave remote sensing, space-based interferometry, solar concentrators, and for dual purposes (e.g. concentrator for power / antenna for communication). In comparison to other mechanically deployable systems, inflatable structures have significant advantages of a much lower cost, weight, and packaging volume, but higher deployment reliability and damping properties. The deployment and geometric accuracy of inflatable structural components have been demonstrated on-ground. In space demonstration of the geometric accuracy that is needed for antenna reflectors is planned for a flight experiment [6], with the objective of verifying the figure of a 14 m antenna. Several of the applications in radiometry, microwave sensing and interferometry require antenna figure accuracy of the order 1 mm rms. Ground test results show that this level of accuracy is attainable, at least initially. It is necessary, however, that this accuracy be maintained throughout the life of the mission as the antenna is exposed to thermal changes and possible aging of the polymer. Further, if an inflatable structural component is cured in space to make it "rigid", the curing process may result in a distorted in-situ rigidized configuration. Thus, to further enhance the long-term performance of inflatable structures in space, this paper explores the feasibility of adaptive concepts as a means of occasional sensing and adjustment of unwanted shape distortions.

The paper reports the results of numerical simulations and laboratory experiments to validate the concepts using generic simple configurations such as the inflated closed tube, and circular membrane in Fig. 1. Other more complex configurations such as in Fig. 2 are investigated analytically. Consistent with the fact that the stiffness of inflatable structures is largely dependent upon the internal pressure, our analysis assumes large elastic deformations with small strains.

* To receive correspondences

The tube in Fig. 1a is made of one mil thick mylar film with one mil thick piezo metallization on one side. Separate patches of conducting piezo are created by chemically etching strips of the metallization. The tube is closed at each end with a 1/2" plastic disk. When one end of the inflated tube is fixed, fine line-of-sight pointing adjustment of the free end can be made relative to the fixed end by controlling the gain in the individual piezo patches. The resulting deformation is shown in Fig. 1a, when only two piezo patches are used - one along opposite sides of the inflated tube. Such a deforming mechanism allows one to make fine configuration adjustments of errors.

The example in Fig. 1b consists of two circular membranes, rigidly clamped along the edge. Inflation pressure is introduced in the air space between the two membranes. Piezo actuation is provided by adhering eight strips of piezo film to the membrane surface. Various deformation patterns describing Zernike polynomials can be created by adjusting the gains in the piezo strips, individually or in combination. For a specific deformation pattern, the gain adjustment is calculated optimally in the least square sense. The results will be included in the paper.

The paper will also describe the analysis procedure and give the results of numerical simulation of the more complex torus/parabolic membrane configuration in Fig. 2. In this example, the parabolic enclosure is inflated and taut at the edge to a torus. The stiffness of the torus arises either from inflatation, or from rigidization. Both regimes are considered, and a number of interesting issues are examined. For example, the surface accuracy of the inflated parabola depends upon several parameters including the initial (uninflated) shape, inflation pressure, edge conditions at the torus interface, elastic interactions between the parabolic membrane and the torus, and the fabrication process itself. Subsequent adaptive correction of deviations from the ideal parabolic shape is then studied by numerical simulation to determine the most effective method of introducing adaptivity in the structure, most suitable type of active elements, and their optimal locations and gains.

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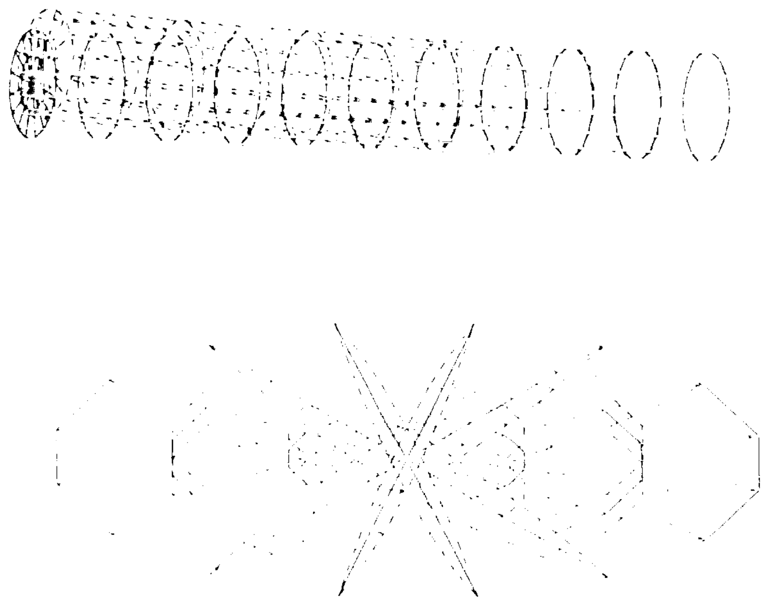

Figure 1. Piezoelectric Actuated Inflated Tube (1a), Inflated Circular Membrane (1b).

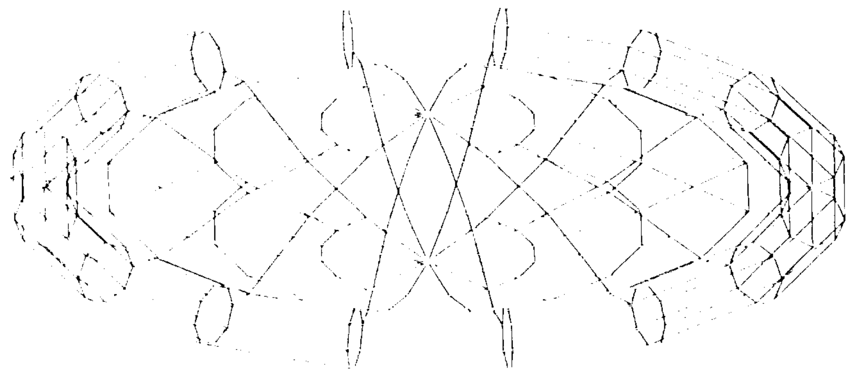

Figure 2. Inflated Parabolic Membrane / Torus.